REFRACTION WITHIN TELESCOPE TUBE.

IT has been supposed that the difference between the zenith-distance of a star obtained by direct observation and that obtained by observing it reflected in a pool of mercury—as it is not fully explicable as the result of the flexure of the telescope-tube—is partly to be accounted for as the result of abnormal refraction in the neighbourhood of the instrument, owing to varying air-temperatures in the room. It is *within the tube of the instrument* that these things are to be looked for.

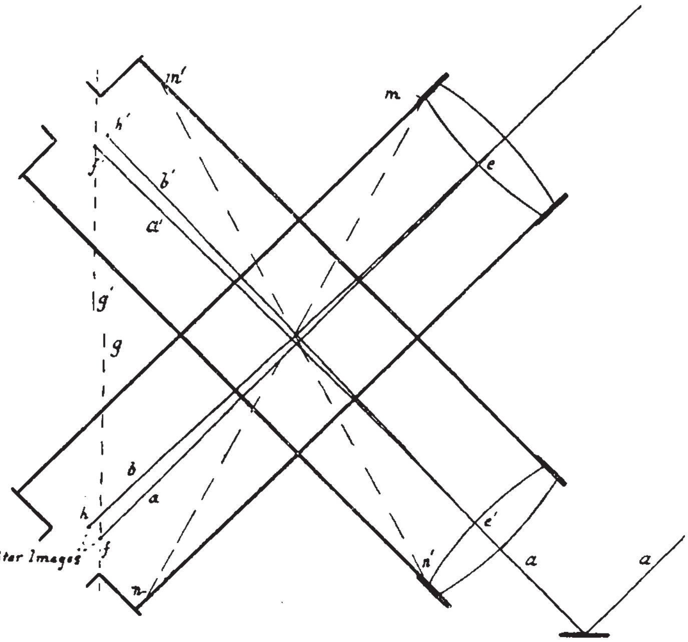

FIG. 1.—*a*, *a'*, Rays normally refracted by horizontal stratification of air. *b*, *b'*, Rays refracted by stratification of air parallel to *mn*, *m'n'*, (inverted refraction). *mn*, *m'n'*, Equal-density surfaces when upper side of tube is cooled.

The air within a room where there is no powerful source of heat and where currents are caused by open shutters, &c., must be very nearly uniform in temperature; neither would it prove the contrary to obtain varying readings of the thermometer within the room, such readings being much affected by radiation from the walls, &c. On the other hand, the air within the telescope-tube must commonly be stagnant, and any cause operating to produce differences of temperature therein will do so effectually. Now in making any observation at considerable zenith distance the upper side of the tube is cooled by radiation, while the lower is protected, and the resulting difference of temperature in the metal of the tube is communicated to the air within, to an extent depending on the time of exposure.

In the diagram (Fig. 1) showing the telescope in the two positions of observing—direct and reflex—the rays *a*, *a'*, are normally refracted and convex upwards, as they would be with horizontal stratification of the air. At any two points at the same level these rays (supposed from the same star) have the same inclination to a vertical line; therefore the zenith distances that would be observed with such refraction (angle *e*, *f*, *g* direct and *e'*, *f'*, *g'* reflex) would be the same—neglecting flexure and the difference of latitude between the trough and instrument. But this result depends on the supposed parallel (viz. horizontal) stratification of the air throughout the course of both rays. When there is a transverse gradient of temperature in the tube owing to the cooling of its upper side and the contiguous air within, the equal-density surfaces are inclined like *m*, *n*, *m'*, *n'*—a difference of temperature of only two-tenths of a degree Fahrenheit will make the air at *m* as dense as it is at *n* if these points differ in level by ten feet—and the stratification of the air, being no longer parallel in the two cases, two different zenith-distances will be obtained. The rays within the tube will then be convex downwards, *b*, *b'*—"inverted refraction"—and the direct observation will give a result in excess of the reflex one by twice the angle *f e h*. So if the results were only affected by this process the Reflex-minus-Direct results would be *negative*. The R – D results obtained in the Greenwich observations are commonly *positive* by reason of the flexure of the tube, and are *reduced in magnitude* by inverted refraction.

In the diagram (Fig. 2) the curve *a* shows the R – D results that would be obtained if affected by instrumental flexure only; from the formula 2(0''·80 sine zenith distance). This value 0''·80 I take to be nearly the correct horizontal flexure (see below). The curve A shows the mean results obtained for the values of R – D in the years 1892-3-4 for south stars, *reflex observation taken first*. The curve B shows the same results for north stars. The curve C shows a special series of R – D results obtained in the year 1894, all from south stars, the direct observation being made first. The differences between these curves severally and the flexure curve *a* are accounted for by the inverted refraction in the tube, and the various values of these differences for the three curves are readily explained :—

(*a*) The north-star-curve differs more from the flexure-curve than the south-star-curve does; the difference in both cases is due to the exposure of the instrument in the position directed to the star (chiefly in the reflex position); but in observing a north star the time of exposure is commonly greater than in observing a south star, as the observation in right ascension is made at the same time, and a slow moving polar star requires more time for this purpose.

(*b*) From Fig. 1 it is apparent that it is at the object-glass end of the tube that the inverted refraction is most effective in separating the star image *h* from the position *f*, where the normal refraction would place it; and of the two observing positions of the instrument, the direct one chiefly affects the object-glass end

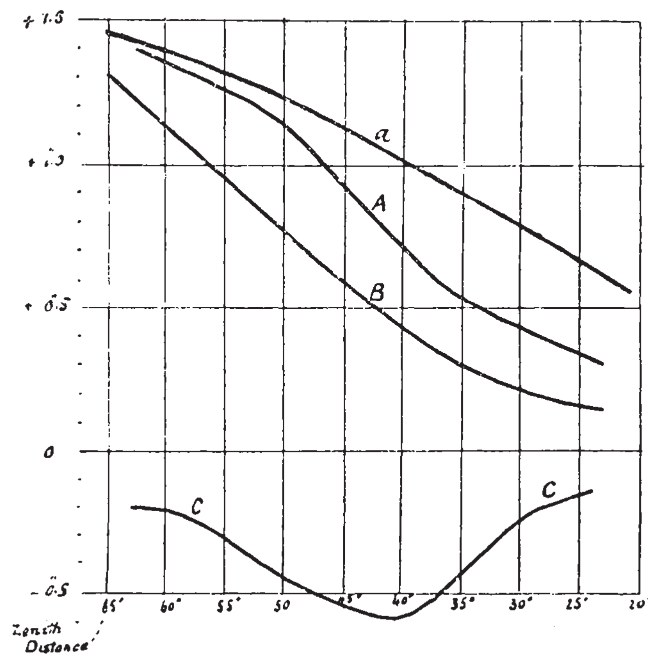

FIG. 2.—*a*, Flexure curve, 2(0''·80 sine zenith distance). A, R – D curve, south stars, reflex observation taken first. B, R – D curve, north stars, reflex observation taken first. C, R – D curve, south stars, direct observation taken first.

by radiation, because in this position it is near the open shutter. In the observations from which the curves A and B are deduced,

the reflex observation is made first, and the instrument is then turned in mid-transit to the direct position, in which the exposure is of very short duration before the observation in zenith distance is made. In the curve C, for which in each case the direct observation was made first, the exposure in the direct position would commonly be considerably greater; and the difference between this and the flexure-curve, attributable to such exposure, is accordingly much greater than the same differences for the A and B curves. Note that the difference becomes smaller under 40° zenith distance; it would be zero in the zenith in all cases.

Other instances of apparent refraction within the tube are found in the Greenwich observations:—

When the north and south collimators are alligned by looking through the holes in the telescope-cube, the collimation-error obtained differs systematically from that obtained by alligning the collimators with the telescope raised out of the way. This can only be explained thus: one side of the instrument is commonly warmer than the other at the hour (8 a.m.) when these observations are made, and the still air in the tube is affected in like manner. If we suppose the air in the spaces A and B, Fig. 3, to differ from each other 0°·5 Fahr. in temperature, and to be separated by a surface which the path of the light between the north and south collimators cuts at an angle of incidence of 80°, the light will be deflected 0″·60 of arc, and the collimation-error obtained would be in error by half this amount, viz., 0″·30,

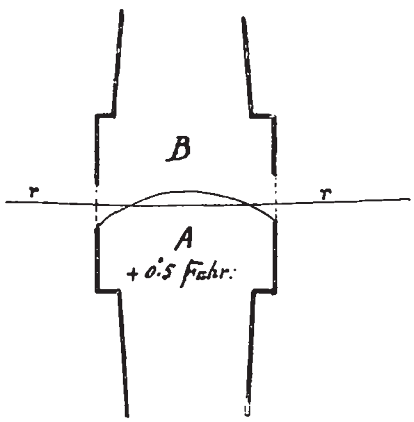

FIG. 3.—*r*, Shows path of light from north to south collimator refracted within cube of telescope when air is unequally heated.

which is about the difference between the values obtained by the two methods.

A similar discordance exists between the results for flexure of the tube formerly obtained by raising the telescope and those recently obtained by alligning the collimators through the cube; and this discordance has a similar explanation. The flexure obtained formerly, which I take to be the more correct, is about 0″·80 of arc, as employed above to explain the R – D discordance.

I conclude that means should be provided—and used—for circulating the air in the tube when any observation—whether of star, of collimation, or of flexure, or otherwise—is made with a transit circle. I would also point out that the source of error here considered is of peculiar importance from the fact that it affects, to a relatively large amount, the zenith-distances of polar-stars, and hence the deduced results for latitude. The error is eliminated in the mean of a reflex and a direct observation taken at the same time.

JAMES RENTON.

SUGAR-CANE EXPERIMENTS.

IN the fourth number of the *West Indian Bulletin*, recently noticed in these columns, many pages were devoted to communications to Dr. Morris, the Imperial Commissioner of Agriculture, from Prof. d'Albuquerque, the Island professor of chemistry, and Mr. Bovell, the agricultural superintendent, in which an elaborate plan was laid down for undertaking an exhaustive investigation into the merits of several varieties of sugar-canes. The very full details therein given should be consulted by any one desirous of mastering the significance of the facts contained in the pamphlet now issued by the Commissioner, giving a "summary of the results of the cultivation of seedling and other canes at the experiment stations in Barbados in 1900." Prof. d'Albuquerque and Mr. Bovell have read a paper on the subject before the Barbados Agricultural Society on the results of the cultivation and yield of selected seedling and other canes, and the pamphlet summarises the essential facts. It is important to remember that the experiments were throughout conducted on the ordinary system of natural cultivation, the planters themselves undertaking to set apart plots of their own plantations, so that the known and the unknown grew side by side, no exceptional treatment being recognised. In this way fairly typical results are obtained, and the results for subsequent years will, therefore, be watched with more than usual interest to see how the character of the season, as well as the quality of the soil, may affect the various canes. For the experiments seven stations were selected, representing the typical soils and climatic conditions of Barbados. Five of the stations were black soil, the other two red soil. At nearly every station there were duplicate plots of each variety, serving to show the variation to be expected with each variety from one part of the field to another. The lowest station was at an elevation of 100 feet above sea-level, the highest 910 feet, the rainfall in the growth period ranging from 56 inches to 89 inches. Fifteen selected varieties of canes were tested on the black soil estates, and ten of them on the red soil estates. For each variety the highest and the lowest yield in tons per acre in the black and the red soils respectively are given, and separate tables for black and red soils show for each cane the number of plots used for the investigation, the yield in tons per acre of canes and also of tops; the juice per cent. by mill; pounds per gallon of saccharose, of glucose and of solids not sugar; the quotient of purity of the normal juice; the juice in gallons per acre; saccharose in pounds per acre; and the sugar in tons per acre, calculated according to a formula supplied by Mr. Douglas, of the Diamond plantations, British Guiana. In the black soil B. 147 heads the list with 3·01 tons of sugar per acre, followed by B. 347 with 2·90 tons, and B. 208 with 2·83 tons, while at the bottom of the list stand D. 145 with 1·82 tons, the Burke with 1·73 tons, and the Bourbon with only 0·47 ton per acre. The White Transparent cane, which is cultivated in Barbados on a larger scale than any other cane, and may therefore be regarded as the standard for comparison, occupies a middle place with a yield of 2·41 tons per acre. In the red soil B. 208 takes first place with 3·34 tons per acre, followed closely by B. 156 with 3·32 tons and B. 147 with 3·31 tons, the lowest being B. 347 with 2·17 tons and B. 254 with 2·14 tons.

The mean results for both soils indicate B. 147 to be the best all-round cane, its yield being 27·52 tons of canes per acre, 3·1 tons of sugar and 6291 lbs. of saccharose, B. 208 occupying second place with respectively 22·55 tons, 3·02 tons, and 5443 lbs., compared with the standard White Transparent results of 20·49 tons, 2·41 tons, and 4528 lbs. A further table gives the results obtained on the three estates of "Dodds," "Pine" and "Waterford" with B. 147 and the White Transparent varieties, the means for the three estates giving B. 147 a yield per acre of 6999 lbs. of saccharose and 3·70 tons of sugar, while the White Transparent yielded 4527 lbs. of saccharose and 2·41 tons of sugar. It will thus be seen that the new seedling, B. 147, is better than the standard by more than a ton of sugar per acre. Looking to the individual and general results, the investigators consider there is a satisfactory degree of agreement under a considerable variety of conditions of culture and growth. B. 147 is regarded as the best all round seedling variety as a plant cane in Barbados, B. 208 giving promise of proving a good red soil plant and ratoon cane. Planters are advised to try, on a small scale, three or four of the varieties which have done best in these experiments, so as to be able to secure eventually the cane best suited to the nature of their particular fields and their own methods of cultivation—features which have, in their way, quite as much weight as the character of the cane itself. While B. 147 seems to be the most suitable cane for particular soils in Barbados, D. 95 appears to be the best for the different circumstances of Antigua. A private letter from Barbados, in which reference is made to the above experiments, states that the officials of the Agricultural Department seem determined on securing improved varie es o that will suit each district, and will yield at least 50 per cent. more sugar than those hitherto cultivated.